FCC-hh analysis chain

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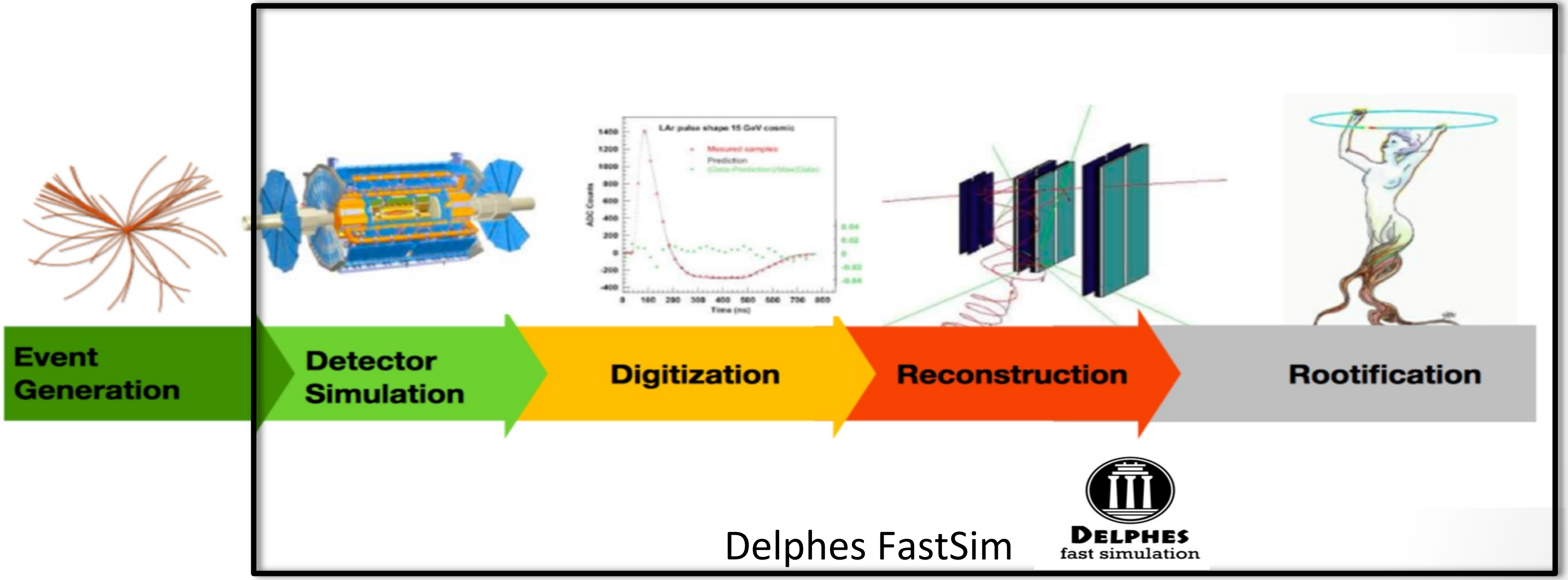
Monte Carlo Event Generation



FCC-hh Framework

Fully integrated analysis chain
Links between various steps
https://github.com/FCC-hh-framework/FCChhAnalyses

1. GridPack producer (adapted from CMS)
   - Makes MG5_aMC@NLO GridPacks
2. LHE Producer
   - Produce LHE files on LSF/condor queues
   - About a 2 billion events produced
   - http://fcc-physics-events.web.cern.ch/fcc-physics-events/LHEevents.php
3. FCCSW
   - Runs Pythia8 parton shower+hadronisation and Delphes with FCC detector
4. Analysis pre-selection
   - Python framework produces flat ROOT trees
5. Analysis final selection
   - Python framework for optimising analysis cut flows and producing
6. Limit setting
   - Atlas inspired tool for limits and significance

   - Number of analyses usign the framework

Creates a database of LHE events
Can produce ~10M events /hour

Creates a database of FCC events
Can produce ~1M events/hour

Use the events in the database to produce analyses templates

Use the events produced in heppy to create stacked plots

Get the cross sections

1. Generation

- https://github.com/FCC-hh-framework/EventProducer

- Start from Madgrap gridpacks but no problem to use other gridpacks
  - Create LHE files and store them on eos
  - List of available samples and statistics for 100TeV (also started 27TeV)
    - http://fcc-physics-events.web.cern.ch/fcc-physics-events/LHEevents.php

- Can also register to the database your own LHE files, they just need to comply with simple formatting rules

2. Simulation (FCCSW Delphes)

- https://github.com/FCC-hh-framework/EventProducer

- From the LHE files, create FCC EDM files for a given Delphes parametrisation
- Also possible to directly simulate events with Pythia8
  - Useful for bunch of signals

- List of available samples and statistics is available for FCC 100TeV :
  - http://fcc-physics-events.web.cern.ch/fcc-physics-events/Delphesevents_fcc_v02.php

- Also started for HE-LHC 27TeV
  - http://fcc-physics-events.web.cern.ch/fcc-physics-events/Delphesevents_helhc_v01.php

3. Flat trees (heppy)

- https://github.com/HEP-FCC/heppy
- https://github.com/FCC-hh-Framework/FCChhAnalyses/

- Within heppy create an analysis directory that contains always the same files:
  - Analysis.py
    - defines the list of modules to be run
      and the list of samples over which to run
      the inputs file lists and cross sections etc… is
      centrally defined and supported (from step 2.)

```
#from heppySampleList_fcc_v01 import *
from heppySampleList_fcc_v02 import *
#from heppySampleList_cms import *


selectedComponents = [
    pp_Zprime_5TeV_ll,
    pp_Zprime_10TeV_ll,
    pp_Zprime_15TeV_ll,
    pp_Zprime_20TeV_ll,
    pp_Zprime_25TeV_ll,
    pp_Zprime_30TeV_ll,
    pp_Zprime_35TeV_ll,
    pp_Zprime_40TeV_ll,
    pp_Zprime_45TeV_ll,
    pp_Zprime_50TeV_ll,
    pp_ee_lo,
    pp_mumu_lo,
    ]
```

3. Flat trees (heppy)

- https://github.com/HEP-FCC/heppy
- https://github.com/FCC-hh-Framework/FCChhAnalyses/

- Within heppy create an analysis directory that contains always the same files:
  - Selection.py -> to define the list of pre-selections (optional)

```
def process(self, event):
    self.counters['cut_flow'].inc('All events')

    #select events with at least 2 leptons
    if len(event.selected_electrons)<2 and len(event.selected_muons)<2:
        return False
    self.counters['cut_flow'].inc('At least 2 same flavor leptons')

    return True
```

3. Flat trees (heppy)

- https://github.com/HEP-FCC/heppy
- https://github.com/FCC-hh-Framework/FCChhAnalyses/

- Within heppy create an analysis directory that contains always the same files:
  - TreeProducer.py -> To define the variables to be stored in the output file
- Analysis flow are fully reproducible, need the outputs to be stored
  - /eos/experiments/fcc/hh/analyses/
  - /eos/experiments/fcc/helhc/analyses/
- A sub-dir is an analysis

RSGraviton_ww	Fix syntax errors
Zprime_ll	add 45 and 50 TeV Z' SSM to leptons
Zprime_tt	Fix syntax errors
h2l2v	added higgs studies configurations
h4l	added higgs studies configurations
haa	added higgs studies configurations
hmumu	added higgs studies configurations
hza	added higgs studies configurations

4. Flat Tree analyser

- https://github.com/FCC-hh-Framework/FlatTreeAnalyzer
- From the files produced in 3.
  - plots and histograms for final analysis for different selections
- Selection based on variables available in output tree
- Templates on github so that we can fully reproduce the results

```
signal_groups = collections.OrderedDict()
signal_groups['m_{Z} = 15 TeV'] = ['pp_Zprime_15TeV_ll']

background_groups = collections.OrderedDict()
background_groups['Drell-Yann'] = ['pp_mumu_lo']

# base pre-selections
selbase = 'lep1_pt > 200. && lep2_pt > 200. && abs(lep1_eta) < 4 && abs(lep2_eta) < 4 && zprime_ele_m>2000'
selections = collections.OrderedDict()
selections['m_{Z} = 15 TeV'] = []
selections['m_{Z} = 15 TeV'].append(selbase)
```

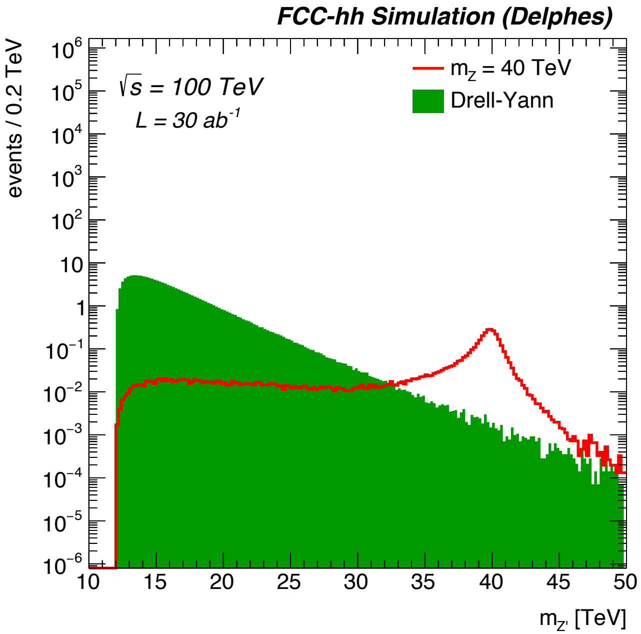
5. Limit, Significance

- https://github.com/FCC-hh-framework/FCCFitter
- ROOSTAT profile likelihood ratio
  - Asymptotic limits
  - Could add any kind of uncertainties (shape or normalizations)
  - Combine channels and correlate nuisance parameters
- Full plotting available to produce:
  - Post-fit plots
  - Ranking plots
  - Correlation matrix
  - Pruning of systematics
- Other higher level macros to:
  - Produce confidence level exclusion plots versus mass
  - Scan the luminosity to get discovery potential

Simple example Z’->ll

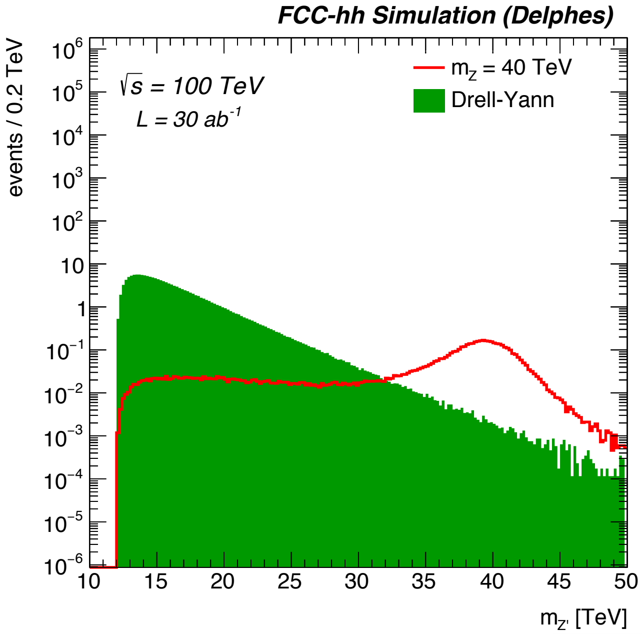
ee

process	yield (30.0 ab-1)	stat. error	raw
m_{Z} = 40 TeV	5.1	0.0	77417
Drell-Yann	128.2	0.1	1811513



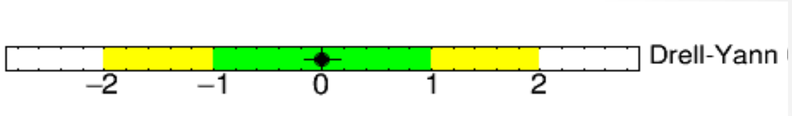
μμ

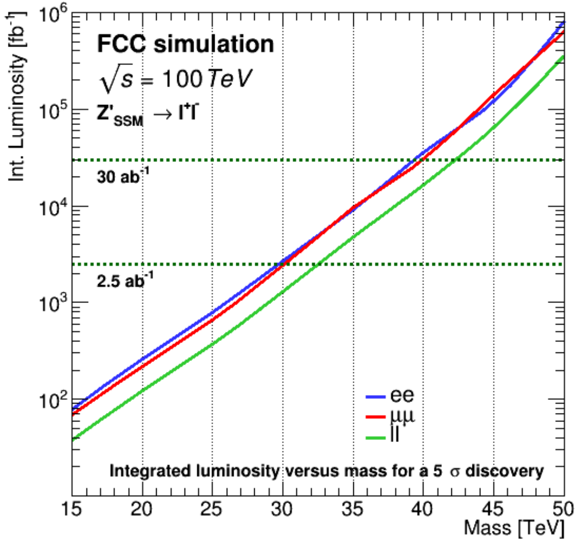
process	yield (30.0 ab-1)	stat. error	raw
m_{Z} = 40 TeV	6.5	0.0	98187
Drell-Yann	141.4	0.1	2449714

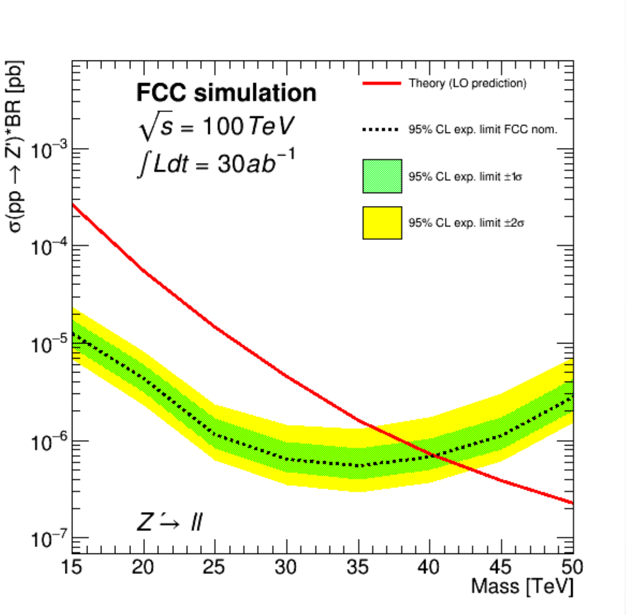


Simple example Z'->ll

50% uncertainty on Drell-Yann Normalisation
Well constrained by profile likelihood







Reach up to 40TeV this very simple case!

Conclusions

- We provided a **simple, highly modular framework** for performing fast detector simulation

- **Integrated** in MG5 suite and in the FCCSW framework and can be used for FCC and HE-LHC studies

- Can be used and configured for:
  - quick **phenomenological** studies
  - as an **alternative for full-simulation** if accurately tuned

- Reproducibility exists, but could be improved

- Already ~20 analyses using this workflow

- Notebooks are being made available:
  - http://swan.web.cern.ch/content/future-circular-collider-fcc